The Effect of Amplitude Modulation Index and Frequency Modulation Index on Total Harmonic Distortion in 1-Phase Inverter

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Abstract. One of the problems that often arise in the conversion process using an inverter is the existence of Total Harmonic Distortion (THD). Harmonics is a symptom of sinusoidal wave formation whose frequency is a multiple of fundamental frequency. Harmonics will cause interference to the system to damage to electrical devices. This paper discusses the effect of modulation index value amplitudo (M_a) and frequency modulation index (M_f) of the value of THD before using the filter. The test was performed using a 1 phase inverter with input variation of the amplitude modulation index and the frequency that was set using PSIM software. The 16 ATMega microcontroller is used as a pulse width modulation (PWM) signal generator. Simulations using a 6 variations value Ma, ie 0.4, 0.6, 0.8 1.0, 1.2, and 1.4, as well as 10 variations of the value of M_f, namely 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100. Based measurement, for M_f are the same, the greater the value of M_a, then the value of THD tends to decrease. Meanwhile, for the same M_a, the greater the value of M_f, then the value of THD tends to decrease.

1. Introduction

The output from alternative energy sources needs to be converted from DC to AC to be used for various needs. To convert DC voltage and current into AC an inverter is required. The inverter is basically a device that converts DC energy to AC [1].

But in the conversion process into voltage and AC currents, there is often a disturbance so that the voltage and current generated by the inverter is not optimal. One of the causal disturbances of the less optimum current and the resulting voltage, is the Total Harmonic Distortion (THD) which is a symptom of sinusoidal wave formation arising from the multiplication of integers with its fundamental frequency [2].

Total Harmonic Distortion (THD) is an important index that is widely used to determine the quality of electrical power in transmission and distribution systems. THD represents the amount of distortion generated by all the harmonic components [3] [4]. Total Harmonic Distortion is the ratio of the rms value of the harmonic component to the rms value of the base component which is usually expressed in

percent (%). The index is used to measure the deviation of periodic waveforms containing harmonics of perfect sine waves [5].

Researchers have done some design to get the best results through efforts to filter out harmonic interference between using Z-Source Inverter method that uses a unique arrangement of impedance to connect the main circuit and the source [6]. In addition, conventional methods such as Genetic Algorithms can also be used to minimize harmonic interference [7].

One other method that can be used is set amplitude modulation index (M_a) and frequency modulation index (M_f). The value of M_a determines the pulse width of the average voltage in one period. The larger the M_a, the larger the M_a, the pulse width of the average voltage during the period will be even greater. Value of M_f determines the fineness of shape memory reference signal is generated [8] [9]. In B. Saragih's study [10], the value of M_a used are from 0.1 to 0.9 with a 0.1 rise. When the value of $M_a > 1$, there will be over-modulation due to the absence of contact between the reference wave and the carrier wave. Value of M_f used was 10 to 14 with the increase in the frequency of the carrier wave 2 should be multiples of the frequency of the output waveform. The larger the value of M_a dan M_f, the interference generated THD smaller [11]. In Syarifudin's study [9], the value of THD will decrease when M_a is 0.1 to 0.9, then the value of THD will increase when M_a is 1 to 4. However, the increase is not as significant in the range of M_a from 0.1 to 0.9. M_f used is fixed-value, which remains at 200. Research done by Syarifudin was only until the simulation, so the loss of components does not affect the value of THD.

Based on the review of the literature, this study discusses the problem of finding the value of M_a and M_f that that produces the smallest THD value in a single-phase inverter. The smallest THD value search is performed before the voltage and current signals are passed to the filter, so that interference with the power system can also be reduced. Variations of indices of amplitude modulation and frequency modulation index were obtained with PSIM software. Variations in the value of M_a to be used is 0.4 to 1.4, while the value of M_f is used from 10 to 100 with an increase every multiple of 10. The range of variation M_f Led is greater than Saragih's research, because it is based on Saragih's research, a small range of $M_{f\,resulting}$ ins the small THD changes as well.

2. Methods

2.1. Process and approach

In this study, 12V DC power supply and 220V AC inverter output are used, with the main component of microcontroller as the control signal generator. The whole set of single phase inverter systems can be seen in the block diagram of Figure 1.
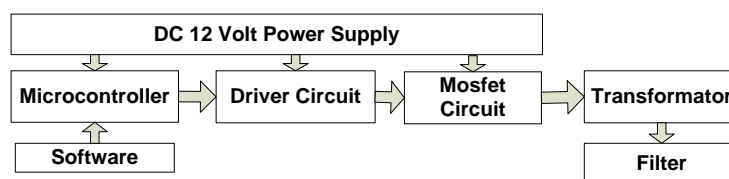

Figure 1. block diagram of a single-phase inverter circuit

The DC power supply supplies power to the microcontroller, the driver circuit and the MOSFET circuit which is then converted to AC. The software section creates a switching pattern whose results are then uploaded into the microcontroller.

The study begins with making unipolar SPWM switching patterns using PSIM to obtain a row of binary values to ignite the MOSFET switches in the circuit. According to Aliyan [12], the use of the SPWM method to adjust the switching, can reduce the THD value from 26.37% to THD voltage 4.58% and THD current 4.33%. SPWM is more effective at reducing THD compared to other switching patterns [13] [14]. In SPWM switching techniques, there are two types of bipolar SPWM and unipolar SPWM, where unipolar SPWM has a harmonic content lower than the bipolar SPWM [15] [16]. Unipolar splitting technique SPWM uses two different sine wave (Vsin) sources with 180 degrees'

phase and one triangle wave source (Vtri). Sine wave as reference signal and triangle wave as carrier signal. Variations M_f and M_a is performed at this stage. Each signal is compared using a comparator as shown in Figure 2.
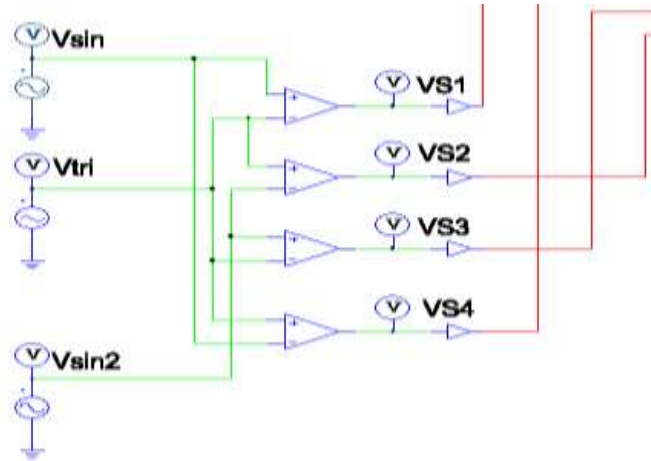

Figure 2. The series of unipolar SPWM on PSIM software.

PSIM software produces 400 data in a period, in the form of a series of binary numbers 1 and 0. The data is grouped per 8 bits to be subsequently converted into hexadecimal format using EXCEL. From 50 data (1/4 wave), then formed into full wave to produce symmetrical wave to eliminate odd harmonics. To upload data to microcontroller used Code Vision AVR software. After the unipolar SPWM switching pattern is uploaded into the microcontroller, the switching pattern is inputted into the MOSFET circuit using the driver circuit in order to ignite the switch on the MOSFET circuit. The output of the MOSFET is a voltage and alternating current (AC).

3. Results and discussion

Variations of amplitude modulation index values used are 0.4 to 1.4 with 0.2 increments. Amplitude modulation index change settings and frequency modulation index are performed on PSIM software. With reference wave amplitude value (A_r) of 1, using the equation:

$$M_a = \frac{Ar}{Ac}, \tag{1}$$

Will get the value of the amplitude of the carrier wave (A_c), $V_{p\text{-}p}$, and DC *offset* as shown in Table 1.

Table 1. Amplitude modulation index

M_a	A_r (V)	A_c (V)	Vp-p triangular	DC offset triangular
0.4	1	2.5	5	-2.5
0.6	1	1.665	3.33	-1.665
0.8	1	1.25	2.5	-1.25
1	1	1	2	-1
1.2	1	0.835	1.67	-0.835
1.4	1	0.715	1.43	-0.715

A_c value of switching is used to have this pattern. While the value of *Vp-p* and *DC offset* are used to set the peak value of the top and bottom of the triangle wave. *DC offset* is a minus value of the amplitude of the carrier wave.

Variations in the frequency modulation index values used are 10 to 100 with the increase in 10. With the wave frequency output (f_o) of 50 Hz, using the equation

$$M_f = \frac{fc}{fo}, \tag{2}$$

Will get the value of the carrier waver frequency (f_c) as shown on Table 2.

Table 2. Frequency modulation index

M_f	f_o (Hz)	f_c (Hz)
10	50	500
20	50	1000
30	50	1500
40	50	2000
50	50	2500
60	50	3000
70	50	3500
80	50	4000
90	50	4500
100	50	5000

Tests carried out using variations of M_f and M_{an} above to see the impact on changes in the value of THD. There are two values of Total Harmonic Distortion obtained namely Total Harmonic Distortion Voltage (THDv) and Total Harmonic Distortion Flow (THDi).

Based on the results of testing with a variety of M_a, M_f THDv and THDi smallest value obtained on the condition of $M_a = 1.4$, $M_f = 90$, and a load of 25 Watt. In this paper, the influence of variations of *the F_f* to THD, seen when the value of $M_a = 1.4$ and a load of 25 Watt. The test results of the effect of frequency modulation index to THDv when $M_a = 1.4$, and load = 25 watts, is shown in Figure 3.
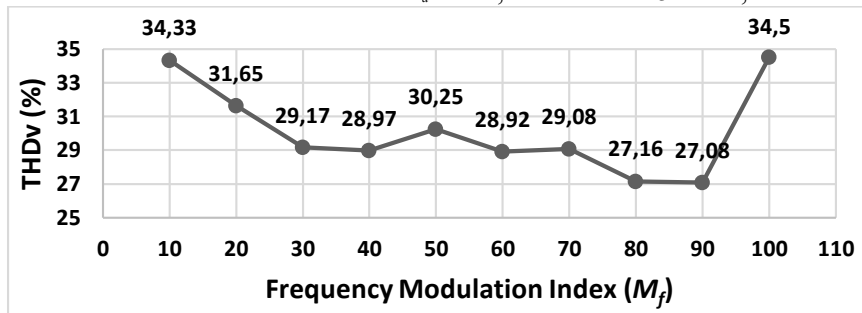

Figure 3. Effect on THDv frequency modulation index ($M_a = 1.4$, Load = 25 watt).

The test results of the influence of the frequency modulation index THDi when $M_a = 1.4$, and load = 25 watts, is shown in Figure 4.
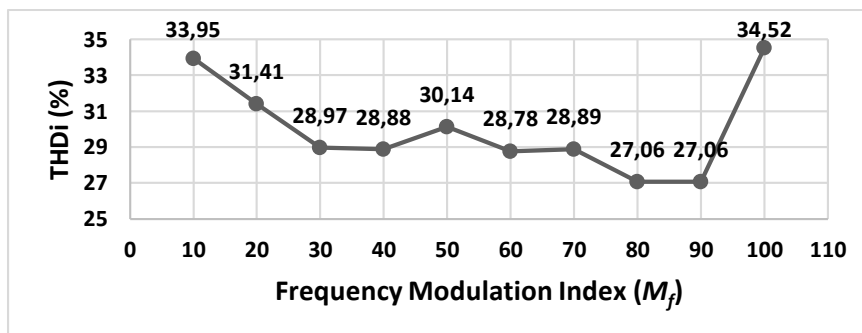

Figure 4. Effect of the frequency modulation index THDi ($M_a = 1.4$, load = 25 watt).

Based on Figure 3 and Figure 4 above, Total Harmonic Distortion (THD) tends to decrease as the frequency modulation index value increases.

Meanwhile, the influence of variation of M_a to THDv, is seen when the value of $M_f = 90$ and load of 25 Watt can be seen in Fig 5.
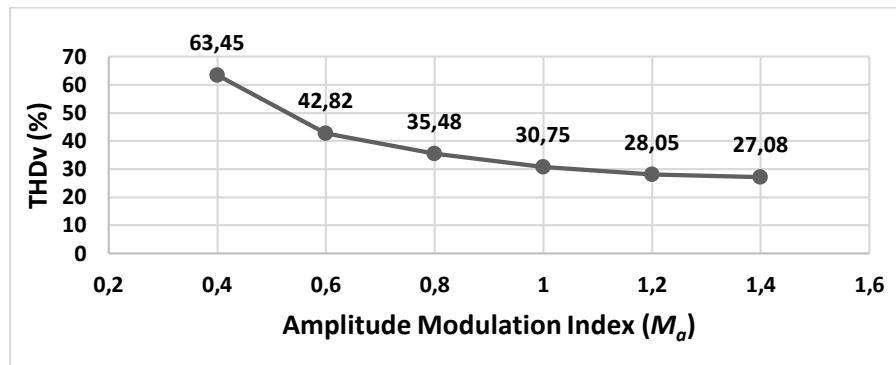
Figure 5. Effect of the THDv amplitude modulation index (M_f = 90, Load = 25 watt).

And the effect of variations of M_a to THDi, Een when the value of M_f = 90 and load 25 Watt can be seen in fig 6.
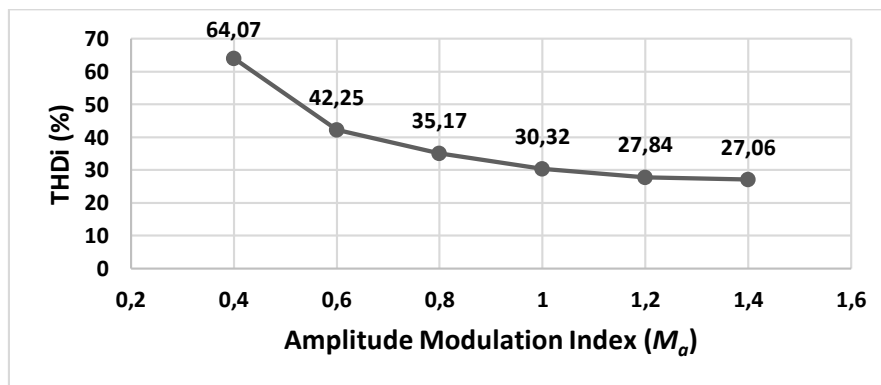

Figure 6. Effect of the THDi amplitude modulation index (M_f = 90, load = 25 watt).

Figures 5 and 6 show that the value of Total Harmonic Distortion (THD) decreases as the amplitude modulation index values increase.

4. Conclusion

Varies amplitude modulation index and frequency modulation index greatly affect the value of Total Harmonic Distortion (THD). When the index value of fixed amplitude and frequency modulation index value is higher, THD value tends to decrease. As when the index value of fixed frequency modulation and amplitude modulation index value is greater, the value of the same THD tends to decrease. For the best value of Total Harmonic Distortion (THD) is the smallest value is THDv 27.08% and THDi 27.06% is when the combination of amplitude modulation index value 1.4 and frequency modulation index value 90.

Acknowledgments

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